Design and Analysis of Helical Coil Spring Suspension System by Using Composite Material

Karthikeyan.S.S[1], Karthikeyan.V[2], Leoni Praveen.C[3],Manigandan.G[4] and Rathish.R[*]

[a]*UG Scholar, Department of Mechanical Engineering, Gnanamani College Technology, Namakkal, Tamilnadu,India*

[*]*Assistant Professor, Department of Mechanical Engineering, Gnanamani College Technology, Namakkal, Tamilnadu,India,*

***Abstract—*:**In this paper, the implementation of composite materials in helical coil suspension system is demonstrated. Previously we were using the conventional steel for helical coil. For required stiffness, the design of such springs is very bulky and costly. Then another implementation is done on the combination of conventional steel and copper and magnesium composite material. It was successful in decreasing the weight, increasing the stiffness of the system. But there are some limitations like cost, manufacturing of copper, very low stiffness of single composite spring which was not much helpful to increase the overall stiffness of the suspension system. So metal matrix composite material is used instead of fibers with combination of conventional steels. The intension behind the use of MMC is to improve overall stiffness and life of the system

Keywords*:* coil springs, primary suspension system, modeling, static analysis, ANASYS 14.0, PRO-E

INTRODUCTION

A vehicle chassis is made up of several systems that all work in union to provide a safe and comfortable ride. The chassis includes the frame, brake system, steering system, and suspension system and wheel assemblies. In present, automobile industries trying to improve the fuel efficiency of automobile vehicle. One of the major factors to maximize the fuel efficiency is weight of automobile vehicle. But we can't compromise with the system like, frame, brake system, steering system, wheel assembly for matter of safety. So we can work on the suspension system to achieve lower weight. Suspension system is one of the important segments of an automobile vehicle. It cushions the ride of the frame, engine, transmission and passengers, while keeping the tires in contact with road under all conditions. In this suspension system, spring is most important part. The function of spring in suspension system is to distort when loaded and to recover it original shape when the load is removed. And to absorb and control energy due to shocks or vibrations. Helical coil spring is normally used for the light vehicle suspension system. The performance of the suspension system is fully depends upon the spring stiffness. If someone wants to reduce the weight of suspension system then he has to consider the other Factors like performance, design constraints, corrosion resistance, fatigue strength of material, cost etc.

Previously the automobile industries were using conventional steel as a helical coil spring in suspension system to improve the performance. Conventional steel is less costly and stronger material than other but the major problem in use of this material is weight. If someone is going to increase the stiffness of the suspension system then he has to improve the design constraints like coil diameter of spring, numbers of coils, length etc. So it affects the weight of suspension system to rise. Indirectly it affects the overall performance. Therefore we have selected composite material which can give average performance with low weight consumption. Also it has other better properties like stiffness, elastic strength, and fatigue

Normally, helical spring failure occur due to high cyclic fatigue in which the induced stress should remain below the yield strength level and also with poor material properties. K Pavan Kumar[1] et.al. (2013) discussed about the static analysis of primary suspension system, their work is carried out on modeling helical spring in Pro/E and analysis in ANSYS of primary suspension spring with two materials Chrome Vanadium is a existing material and 60Si2MnA steel is a new material, the conventional steel helical spring 60Si2MnA is proved as best material for helical spring by reduction of deflection and overall stress. Priyanka Ghate[2] et al. investigated the failure of A Freight Locomotive helical spring by redesigning to improve the durability and ride index in this the composite suspension system can sustain the loads in under normal operation conditions and maintains the ride index but the failure occurs during cornering and hunting speeds to avoid this the study of dynamic behavior of a composite spring is analyzed. The dynamic analysis was performed using ADAMS/Rail at four different velocities and three different track conditions and numerical simulation also carried out. The results shows that the stress value obtained from numerical simulations in ADAMS was verified with analytical design calculations for the spring and the ride index was found to 1.78 which was 8% better than the earlier spring. It is concluded that the new spring design can enhance durability and ride index Mehdi Bakhshesh[3] et al.(2012) worked on optimum design of steel helical spring related to light vehicle suspension system under the effect of a uniform loading has been studied and finite element analysis has been compared with analytical solution. This spring has been replaced by three different composite helical springs which are made of E-glass/Epoxy, Carbon/Epoxy and Kevlar/Epoxy. The optimum design based on the parameters of weight, maximum stress and deflection and have been compared with steel helical springs. It has been shown that spring optimization by material spring changing causes reduction of spring weight and maximum stress considerably. N.K.Mukhopadhyay[4] et.al (2006), investigation on the premature failure of suspension coil spring of a passenger car, which failed during the service within few months and identified the reasons for the failure. This investigation micro structural analysis, SEM analysis, hardness testing, and chemical analysis. The results stated that the inherent material defect in association with deficient processing led to the failure of the spring. Reduction in weight of automobile vehicles is economical for automotive industry, so P.S.Valsange[5] et. al (2012), investigated the effect of parameters on the quality of coil springs. And also estimated factors affecting on the strength of coil spring, by using F.E.A. approaches. Thus the springs are to be designed for higher stresses with small dimensions to have better spring design which leads to save in material and reduction in weight. It is observed that if the inner side of the coil spring is shot penned the stresses on inside coil surface reduces and fatigue life of coil spring increases. S.S.Gaikwad[6] et.al (2013),examined on Static Analysis of Helical Compression Spring Used in Two-Wheeler Horn, using NASTRAN solver and compared with analytical results .Static analysis determines the safe stress and corresponding pay load of the helical compression spring. it is concluded that the maximum safe pay load for the given specification of the helical compression spring is 4 N. At lower loads both theoretical and NASTRAN results are very close, but when load increases the NASTRAN results are uniformly reduced compared to theoretical results. The objective of the present work is analyze the safe load of the light vehicle suspension coil spring with different materials and attain the optimum design.

Helical springs exhibit high sensitivity to supporting conditions. The shape of end coils influences the stiffness of spring. The way of mounting of the spring's end coils influences the susceptibility to buckling. In available literature, one can find formulas allowing calculation of the change of axial twisting angle of statically-compressed helical spring's end-coils, but simplifications in these formulas cause that they cannot be used for large-deflection cases.

COMPOSITE MATERIALS

A composite material is a combination of two or more materials that results in better properties than those of

Individual component used alone. The main advantage of composite materials is their higher strength and stiffness, combined with low density, when compared with heavy materials, allowing for a weight reduction. Also they possess significantly improved properties including high specific modulus, good wear resistance compared to unreinforced alloys. It is observed that composite materials have lower density and elastic modulus which results the greater specific energy. Such properties make a very strong candidate in such applications Due to such advantages of composite material, many researchers have taken interest in this area. Mehdi Bakhshesh and Majid Bakhshesh has tested behavior of helical spring by replacing steel spring with three different composite helical springs including E-glass/Epoxy, Carbon/Epoxy and Kevlar/Epoxy. And the results are compared. Shiva Shankar and Vijayarangan have studied a low cost fabrication of complete mono composite leaf spring and mono composite leaf spring with bonded end joints. T. S. Manjunatha and D. Abdul Budan have experimented on the strength of the helical spring with the use of fiber reinforced composites. In here by using of a steel alloy, copper, magnesium. All of the above research papers, shows the feasibility of use of composite materials. But these fiber composites are effective in light weight applications only. Steel alloy is used in this research because it has high strength, low durability, much inability ,availability and cost is attractive compared to other composite materials. However, the scope of these properties can be extended by using copper matrix composite materials.

MATERIAL PROPERTY

I. STEEL ALLOY

Properties	Value
Tensile strength	655MPa
Yield strength	415MPa
Elastic modulus	190-210GPa
Poisson's ratio	0.27-0.30

Table 1

II. COPPER

Properties	Value
Tensile strength	820MPa
Yield strength	460MPa
Elastic modulus	117GPa
Poisson's ratio	0.34

Table 2

III. MAGNESIUM

Properties	Value
Tensile strength	380MPa
Yield strength	275Mpa
Elastic modulus	44.8Gpa
Poisson's ratio	0.35

Table 3

DESIGN OF SPRING

After selection of material, we have tested this material by using previously suggested designs at the working load of 800N. initially we are testing this material by analytical method

Some important notifications

1. Deflection $\delta = \frac{64\, W\, R^3\, n\, Sec\, \alpha}{d^4}\left(\frac{\cos^2\alpha}{C} + \frac{2\, \sin^2\alpha}{E}\right)$

Where,

W = Axial load N
R = Mean radius
α = Helix angle
d = Outer diameter
C = Modulus of rigidity
N = no. of. Coil
E = Young's modulus

2. Bending Stress $\sigma_b = \frac{32\, W\, R\, Sin\alpha}{\pi d^3}$ N/mm^2

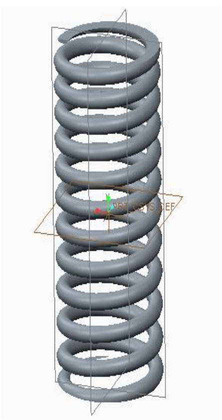
3. Shear Stress $\tau = \frac{16\, W\, R\, Cos\, \alpha}{d^4}$ N/mm^2

4. Deflection $\delta = \frac{64\, W\, R^3\, n\, Sec\, \alpha}{d^4}\left(\frac{\cos^2\alpha}{C} + \frac{2\, \sin^2\alpha}{E}\right)$

5. Stiffness K = $\frac{E}{\delta}$ N/mm^2

Where, **N** is the number of active turns and **G** is the shear modulus of elasticity. Now what is an active coil? The force F cannot just hang in space, it has to have some Material contact with the spring. Normally the same spring wire e will be given a shape of a hook to support the force F. The hook etc., although is a part of the spring, they do not contribute to the deflection of the spring. Apart from these coils, other coils which take part in imparting deflection to the spring are known as active coils.

Stiffness of the helical spring
$K = \frac{W}{\delta}$
Here we conclude on the discussion for important design features, namely, stress, deflection and spring rate of a helical spring.



Specification of spring:
Wire diameter = 10mm, Coil outer diameter=66 mm, Coil free height =210 mm, No. of active Coils =13, pitch =12.5 mm, and test load on each spring =2750 N.
In this paper we used the parallel spring orientation because individual spring does not sustain higher load. The parallel spring principle is given below.

We know that, for parallel spring
F = $F_1 + F$
$\delta K = \delta_{12} K_1 + \delta$
But, $\delta = \delta_{12} = \delta$
Therefore,
K = $K_1 + K$

Because of the parallel combination, the total load is distributed into two so the total load acting on single spring is less. In this paper, we have tested designs of springs with and without combination and the result is compared.
Result of load test on individual spring design

s.no	δ (mm)	τ (N/mm^2)	K (N/mm)
1	91.33	462.18	30.11
2	2.6568 $\times 10^{-4}$	0.13049	10350.79 $\times 10^3$
3	4.18$\times 10^{-4}$	0.13049	6.56 $\times 10^6$
4	7.6518$\times 10^{-5}$	0.13049 N/mm^2	35.93 $\times 10^6$

Table 4

Modelling of helical spring

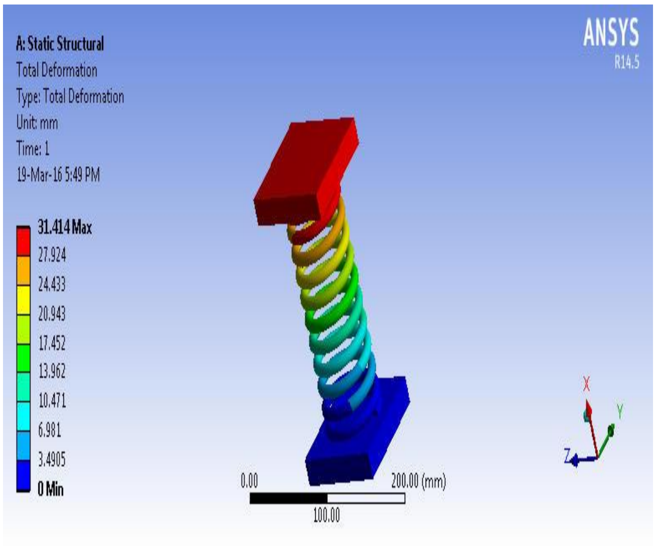
A coil spring is designed by using PRO-E as per the specifications and analysed by ANSYS 12.0software. In this the spring behaviour will be observed by applying different materials loads, to optimum stresses and the result shows best material. Model of the spring will be first created by using PRO-E. Begin by drawing a line of 152 mm length and it is the free height of spring. The line is at a distance of 56.94mm from vertical axis and it is outer diameter of the coil. Next enter the pitch of spring. Pitch is calculated by free height of coil the spring divided by the Number of turns. In this 152/11=13.8mm. Create the Circle of wire diameter 9.49mm of spring and create Solid model of helical spring

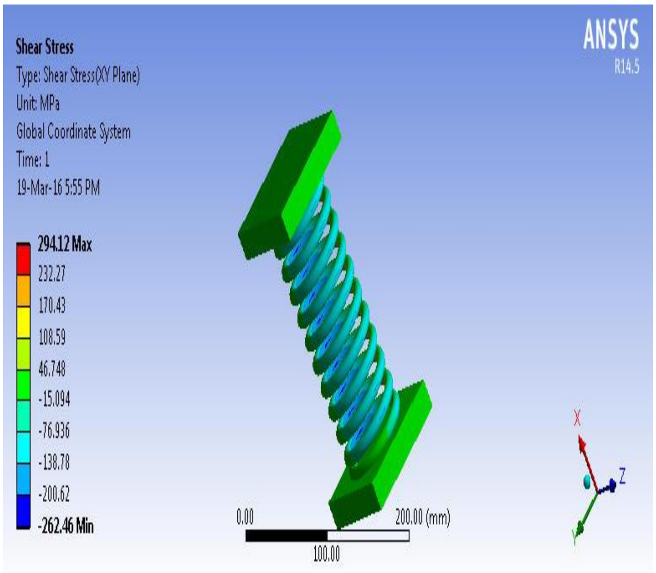
Analysis of modelled helical coil spring

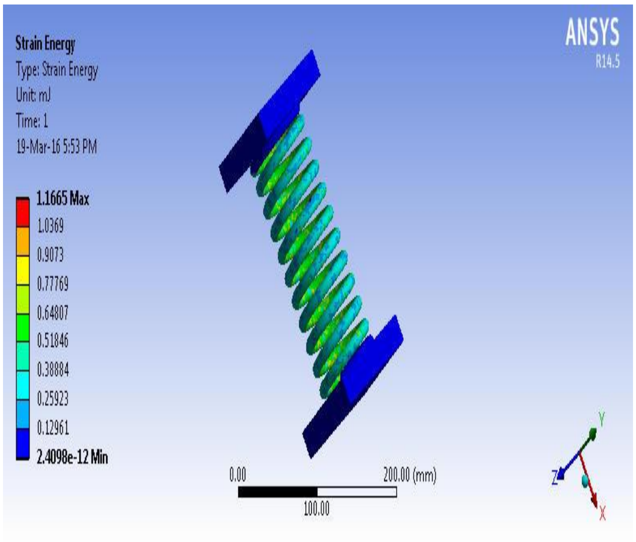
A model of the helical spring was created using Pro/Engineer software. Then the model will be imported to analysis using FEA uses a complex system of points called nodes which make a grid called a mesh. This mesh is programmed to contain the material and structural properties which define how the structure will react to certain loading conditions. Nodes are assigned at a certain density throughout the material depending on the anticipated stress levels of a particular area. This model includes static analysis with different materials to optimum the stresses.

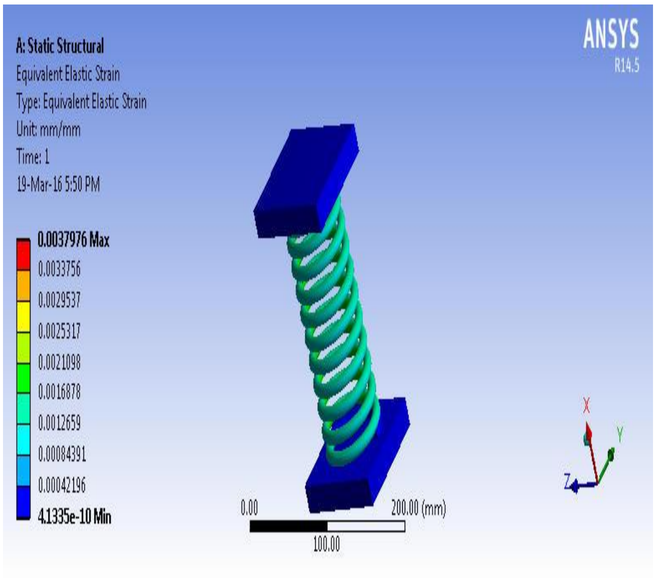
Static analysis:

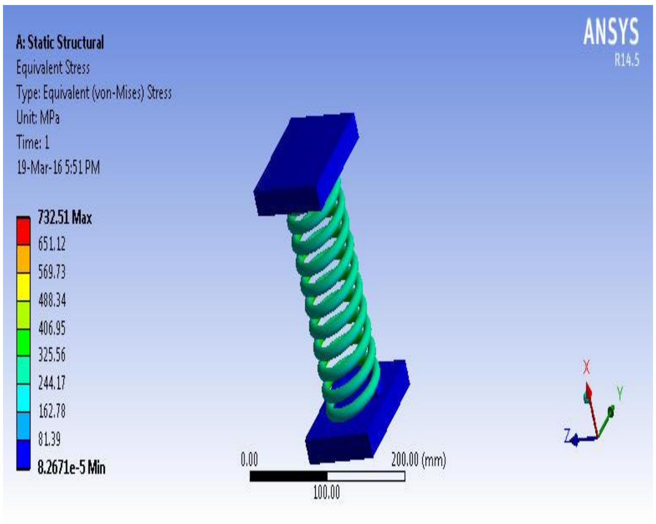
Structural analysis consists of linear and nonlinear models. Linear models use simple parameters and assume that the material is not plastically deformed. Non-linear models consist of stressing the material past its elastic capabilities. The stresses in the material then vary with the amount of deformation as in it.











CONCULSION

Because of the combinational use of composite material with steel, the overall weight of the system also reduced. In above table, it has been observed that the weight of the system is reduced up to 60% and the volume of the system is reduced up to 75% for same loading conditions. Therefore the light weight system is achieved. So it will help to increase the fuel efficiency of automobiles. Also it can be useful for heavy load applications where the weight is the major criteria. The cost of the overall system is higher than conventional system but because of the other advantages, it can be considerable. For special purpose applications, this system is very much efficient.

REFERENCE

1. Bryan Harris-" Engineering composite materials" Calculator of Helical coil spring- http://www.tribology-abc.com/calculators/t14_1.htm
2. Mehdi Bakhshesh and Majid Bakhshesh - "Optimization of steel helical spring by composite spring", VOL. 3, NO. 6, JUNE 2012, ISSN: 2045-7057.
3. Shiva Shankar and Vijayarangan - "Mono composite leaf spring for lightweight vehicle- design, end joint analysis and testing". Vol. 12, No. 3. 2006.
4. T. S. Manjunatha and D. Abdul Budan - "Manufacturing and experimentation of composite helical springs for automobile suspension". Vol.1, No.2, July 2012, ISSN 2278-0149.
5. H. K. Shivanand - "Comparative Studies on Mechanical Properties of Aluminium Based Hybrid Composites Cast by Liquid Melt Technique and P/M
6. Route". Materials Processing for Properties and Performance (MP3), Vol.3, 2004.
7. Timoshenko, S. P., and McCullough, G. H., 1935, *Elements of Strength of Materials*, 2nd ed., Van No strand, New York.
8. Popov, E. P., 1952, *Mechanics of Materials*, 1st ed., Prentice-Hall, Englewood Cliffs, NJ.
9. Timoshenko, S. P., and Young, D. H., 1968, *Elements of Strength of Materials*, 5th ed., Van Nostrand, New York.
10. Boresi, A. P., and Schmidt, R. J., 2000, *Advanced Mechanics of Materials*, 6thed. Wiley, New York.
11. Wahl, M., 1944, *Mechanical Springs*, Penton, Cleveland, OH.